THE MARS PATHFINDER ATTITUDE AND INFORMATION MANAGEMENT SYSTEM

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Abstract

The Mars Pathfinder Mission is developing a small, low cost and mass vehicle that demonstrates interplanetary cruise, entry, descent, and upright landing systems for use in future missions. The landing vehicle will carry a micro-rover to the surface of Mars. Imaging, atmospheric structure and meteorological experiments will be carried out using instruments aboard the lander. An elemental analysis experiment using an alpha, proton, x-ray spectrometer will be carried on the micro-rover. The mission will characterize surface morphology and geology, acquire elemental compositions of rocks and surface materials, obtain atmospheric measurements, such as pressure, temperature and accelerations, demonstrate utility and mobility of a small rover on the Martian surface and return engineering data on the condition and configuration of the lander after landing. The Mars Pathfinder Flight System Attitude and Information Management (AIM) subsystem provides the overall control of the vehicle throughout the mission. The AIM subsystem utilizes a low cost, centralized system architecture using a radiation-hardened IBM RS 6000 computer. In this paper, an overview of the Mission and Flight System design will be presented. The processes being developed by Pathfinder for NASA's Discovery-class of missions to enable this "faster, better, and cheaper" implementation approach and how they are being applied to AIM will also be described. in addition, the design details of the AIM subsystem will also be discussed. Finally, the approaches being used on the lander to implement software and spacecraft fault protection functions will be addressed.

1- Introduction

Mars is the most Iiarth-like of the terrestrial planets and may have supported life. It has stirred interest and imagination for many decades and will continue to be the target for human exploration in the next century. A single Mars Pathfinder Flight System will be launched to Mars in the window December 5, 1996 to January 3, 1997 on a Delta 11. Landing is set for July 4, 1997. The Flight System is spin stabilized during cruise, spinning at 2 +/- 0.1 rpm, with the spin axis and medium gain antenna pointed to Earth except for the first 20 days after launch, when the spin axis is pointed closer to the sun line. After the first 20 days and except for trajectory correction maneuvers (TCMs), the spacecraft will maintain an Earth pointing attitude until Mars atmosphere entry. The first two TCMs will be performed in a "turn and burn" mode. The last two maneuvers will use a "pulsed lateral" TCM; thrusting along or perpendicular to the spin axis. All cruise critical events arc telemetered in real time to Earth.

Seventy-two hours before Mars arrival, the Flight System will turn approximately 7° to its entry attitude and, while in communication with Earth, jettison the cruise stage, and enter directly into the Mars atmosphere, braking with an aeroshell, parachute, small solid retrorockets and air bags.

The entry velocity is 7.6 km/see compared with Viking at 4.6 km/sec which entered from orbit. Mars Pathfinder's entry angle is 15.5° +/- 10 (90 ° would be straight down). A peak atmospheric deceleration of 25 g's is encountered 32 km above the surface. The parachute is deployed at Mach 1.2 at an altitude of 10 km, 100 seconds after atmospheric entry.

Entry, Descent and Landing (EDL) engineering telemetry will be transmitted to Earth in real time to the extent possible. Before parachute deployment, Earth remains near the spin axis behind the craft and communication to earth is through a low gain antenna at 40 bps. After chute deployment, the Earth moves to approximately 90° from the spin axis, making communications more difficult. For this phase of the mission, a telemetry rate of at least at 20 bps is planned, but it may be revised to simply maintaining carrier presence detection only. EDL, lasting for 5 minutes, will be supported with the Deep Space Network's (DSN) 70 m arrayed with available 34 m antennas.

On the surface, the lander will right itself by deploying, petals that expose solar panels to the Sun for powering surface operations. After landing, the lander will transmit stored EDL data and real time lander and rover engineering telemetry first. Panoramic images of the surface will be also transmitted to Earth the first day. The rover will be deployed as early as the first day to start its surface operations. The rover conducts surface mobility experiments, images rocks and soil and deploys the APX on soil and against rocks. While 30 day and 7 day primary surface missions are-planned for the lander and rover, respectively, close to 100% of all lander and rover engineering and science objectives arc achieved nominally in the first fcw days of surface operations. Currently, no constraint precludes operations of the lander or the rover past their primary mission requirements.

The Pathfinder scientific payload includes: instrumentation for measuring atmospheric and landing deceleration; pressure and temperature during entry and while on the surface; a 122 spectral channel, stereo lander camera for surface and atmospheric imaging, including imaging magnetic properties targets, a wind sock and support of rover navigation; and the rover-deployed APX for elemental composition measurements of rocks and soil. The rover carries aft and forward cameras for demonstrating autonomous hazard avoidance and imaging its local surroundings, soil and rocks, and the lander.

11- Mars Pathfinder Approach

Pathfinder is in a special "faster, better, cheaper" project operating mode, accomplishing a challenging mission at low cost and fixed price, using a "Kelly Johnson" like skunks works approach, focusing on a limited set of objectives, and streamlining project approaches and minimizing bureaucratic interference. NASA's office of Space Science is developing Pathfinder. The Advanced Concepts and Technology Office teamed with the Space Science Office is developing the Pathfinder rover.

To land on Mars with a rover at low cost, the Pathfinder project:

- Acquired institutional support priority within JPL, in particular, in quick formation of a motivated, projectized, collocated "skunks works" team
- Achieved Up-Front Agreements with JPL and NASA management
- Leveraged NASAS investment in JPLs planetary mission infrastructure, making cost effective use of computer aided electronics design tools, mission design tools, navigation techniques, multi-mission Ground Data System (GDS) and Mission Operation System (MOS)

capabilities, and the JPL Flight System Test Bed

- Balanced the use of available and new technology, each application weighted carefully as to its contribution to low cost and risk
- Supported NASA in streamlining the lander camera AO process which led to selection of a powerful camera utilizing the Cassini Huygens-proven CCD and its associated electronics
- Practiced concurrent engineering from the outset among mission, navigation, flight system, instruments, rover, ground data system, operations, product assurance, and procurement
- Developed a centralized system architecture in the AIM subsystem that uses a single flight computer for control of cruise, EDL, and surface operations
- Accomplished early proof of concept testing for new technologies
- 1s performing early interface/functional testing centered around the AIM subsystem in the JPL Test Bed among the flight system, instruments, rover, flight software, GDS and MOS sequences

The most important feature of Pathfinder's approach is collocation of all key team members on the same floor of one building around the JPL Test Bed. Collocation simplifies lines of communication and facilitate rapid iteration of requirements, and resolution of issues and problems. The project is self-contained, including collocated product assurance and procurement teams.

Mars Pathfinder's flight system is self contained, will cruise to Mars on its own, directly enter the Martian atmosphere without orbiting Mars, aerobrake with a Viking derivative aeroshell and parachute, but land. semi hard. at up to 20 m/s horizontal and up to 20 m/s vertical velocities. Landing will be limited to <50 g's using an air bag system designed to accommodate 1/2 m size rocks. The lander tumbles and rolls across the surface and rights itself using petals much like an opening flower. Pathfinder's telemetry link with earth is direct and access to both soil and rock is with the rover. Pathfinder's lander and the rover arc both solar powered.

The Pathfinder Flight System is a blend of available and new technology, each application is carefully weighed as to its contribution to performance, risk and cost. Pathfinder uses the following available equipment or designs:

- Cassini electronics and related test equipment
- Magellan Star Scanner
- Adcol Sun Sensors
- Viking heritage aeroshell and parachute designs
- IIOD developed Rocket Assisted Decelerator (RAD) rockets and altimeter

Pathfinder's kcy new technology uses include:

- A free ranging rover with on-board autonomous navigation
- A solid state X-Band power amplifier
- A radiation hardened IBM RS 6000, 32 bit flight computer
- Air bags adapted for usc in Mars atmosphere
- Lander image data compression

The rover, X-Band power amplifier, and EDL (in particular the air bags) represent the major Pathfinder developments. Significant work was accomplished on each of these in the pre-project phase including proof of concept air bag tests at Sandia, rover mobility tests and breadboard power amplifier development at JPL.

The EDL system is comprised of subsystems with heritage requiring little or no development (air bags are the exception); the challenge lies with incorporating these into an effective, space qualified system. While EDL system demonstration and qualification testing arc of major importance, they are not on the critical path relative to Assembly, Test and Launch Operations subsystem, which embodies the central computer, the flight software, the solid state power amplifier and the rover. A drawing of the Pathfinder Flight System in the landed configuration is shown in Figure 1. It also shows the Integrated Electronics Module (lEM) which houses the majority of the AIM subsystem electronics that land on Mars.

Pathfinder's major challenges is to accomplish both the Pathfinder and rover developments within their cost caps: 171 and 25 Mil $, real year, respectively. The other major challenge is accomplishing the development in 3 years. This is a lesser challenge because of the quick start made possible by the pre-project phase. ATLO has been planned at one shift per day, 5 days per week in Pasadena, and 6 days per week at the Cape. The project holds 22 weeks of schedule margin distributed in ATLO, in addition to extra shifts and weekends which arc book kept as a lien on reserves.

III- AIM Subsystem Description

Rapidly advancing technical requirements and growing economic constraints on interplanetary spacecraft are driving spacecraft designers to rely more on small, light weight commercially available equipment rather than equipment fashioned laboriously for "one-of-a-kind" missions. Mars Pathfinder's Flight System design reflects this. It draws heavily on advanced, low-cost technologies that are readily available in the commercial and defense space industries. This is true from the electronics parts level to the assembly/subsystem level. The architecture integrates these technologies to produce a highly reliable system.

The Mars Pathfinder Attitude and Information Management (AIM) subsystem is built around a low cost, centralized system architecture using a radiation-hardened IBM RS 6000 computer. This computer is used to provide control of power, propulsion, telecommunication and attitude control during cruise to Mars; providing for sequencing, pyro firing, and telecommunications control during EDL; providing for power and telecommunications control for lander operations; processing engineering, rover and instrument data for transmission; support of rover surface operations; providing flight system fault management and safing during cruise, EDL and lander surface operations; and operating in the cruise, EDL and Mars surface environments. Other commercial technologies being used in the AIM subsystem include the following:

- Electrically Erasable PROMs(EEPROM)
- Field Programmable Gate Arrays (FPGAs)
- VX Works Operating System
- VM Ebus backplane
- Commerical DC-DC converters

A block diagram of the AIM subsystem is shown in Figure 2.

The AIM subsystem has a cruise mass of 29 kg and a landed mass of 13.5 kg. During cruise its maximum power usage is 51.6 W. During landed operation it consumes 32.5 W during normal day operations and 8 W at night. It also has the capability at night in an emergency to operate in a "hibernation" mode wherein it consumes approximately 1 W.

The AIM subsystem is required to perform the following tasks:

- Acquire the sun following separation from the launch vehicle
- Acquire stars for celestial attitude reference
- Point the spacecraft spin axis to maintain telecommunications over a fixed medium gain antenna during cruise to an accuracy of 5°
- Receive, process, and manage command and data streams, including the execution of stored nominal and contingency command sequences and recording critical telemetry data
- Perform spacecraft commanded turns

of stored nominal and contingency command sequences and recording critical telemetry data

- Perform spacecraft commanded turns
- Control the spacecraft attitude and spin rate during cruise
- Perform trajectory correction maneuvers using reaction control thrusters
- Perform H-vector point i ng control prior to Mars entry to an accuracy of 1.5°
- Execute all events for the Entry, Descent and Landing (EDL) phase including processing accelerometer data to identify time of parachute deploy, radar altimeter data to identify time of impact, and to fire all EDL pyrotechnic devices. AIM also collects and stores all science data collected during EDL.
- Provide sufficient engineering data in the telemetry stream to support ground operations and interpretat ion of science and Rover data
- Provide fault protect ion for spacecraft and AIM functions
- Activel y control power and temperature
- Control and collect data from the imaging and Atmospheric Science Instruments subsystems
- Perform HGA Earth acquisition following landing using camera imaging data to locate the Sun
- Provide High Gain Antenna tracking of the earth to an accuracy of 3.5°
- Actively compensate camera and HGA pointing for changing tilt during landed operations
- M an age the Lander to Rover communications link and collect and store uplink and down link data
- Perform image data compression

The AIM subsystem is the electronics and control center of the Mars Pathfinder Flight System. Its performance is critical to the collection, storage, processing, and distribution of engineering and science data, issuing commands for all subsystems, performing attitude control, and for operating the interfaces with the Rover and Mission Operations System.

The AIM interacts with the following subsystems:

- Imager for Mars Pathfinder (1 MP)
- Propulsion (PRO)
- Telecommunications (TEL)
- Power and Pyro Switching (PPS)
- Radar Altimeter Subsystem (RAS)
- Atmospheric Structures
- Instrument/Meteorology (ASI/MET)
- Lander Mounted Rover Equipment (LMRE--Rover modem)
- Heat Rejection(}IRS)

Each external interface is unique. The IMP is mounted in the AIM VME bus and communicates with AIM via that bus. The Propulsion subsystem is operated by the Propulsion Drive Electronics. Uplink and down link data are transferred between the AIM and TEL subsystems using the Hardware Command Decoder (for receipt of uplink data) and Reed Solomon Down link boards (for transmission of down link data). The ASI/MET and Radar Altimeter are commanded and deliver telemetry to AIM. PPS power and pyro relays are driven from the PPS Interface board, and the Mars Pathfinder Flight Computer (MFC) communicates with the rover using the LMRE.

The AIM subsystem is composed of two modules--the Lander Module and the Cruise Stage Module. Each module is bounded by the dashed lines and is a logical decomposition of the AIM subsystem. The Lander Module houses the computer and all electronics and equ ipment required for landed operat ions--these electronics are housed in the Integrated Electronics Module (IEM) developed by the AIM subsystem. The Cruise Stage Module contains all electronics and equipment mounted on the flight system's cruise stage and is jettisoned prior to atmospheric entry. The Cruise Stage Module is composed of the Cruise Stage Electronics Module (CEM)--another housing the AIM subsystem is responsible for--and all of the other equipment on the Cruise Stage the AIM subsystem is developing

The AIM computer uses a 32-bit RAD6000-SC (Single Chip) processor operating a VME bus and is called the Mars Pathfinder Flight Computer (MFC). The MFC also operates a UART (RS-232) interface used for communications with the Rover. The MFC is a variable speed processor; the AIM will operate using these 3 rates: 1.25, 5, and 22 MIPs. The MFC contains 128 Mbytes of Dynamic RAM (DRAM) memory for the operational storage of data, sequences, and flight software (FSW). Flight software nominally executes from this memory. The performance characteristics of the MFC are shown in Table 1.

Non-volatile memory storage is provided on the PROM (Programmable Read Only Memory) assembly. The PROM assembly uses Electrically Erasable PROM (EEPROM) to store flight software, sequences, and mission critical data, all of which can be updated in flight. The PROM assembly protects all data written to it by encoding the data so single-bit errors can be corrected when the data is later read by the MFC.

The Power and Pyro Switching Interface (PPS I/F) board accepts commands from the MFC and provides the relay drive signals to the power distribution unit, shunt regulator, and pyro switching unit of the PPS subsystem. Power distribution is inhibited via a triple relay to the main battery. Pyro switching is inhibited via a double series relay. The first latching relay allows for the system to be armed, and prior to Flight System/upper stage separation, it can only be armed from the ground. The second latching relay allows for the system to be enabled, and it can only be enabled following spacecraft separation from the PAM-D upper stage. This configuration prevents inadvertent single-fault induced pyro events from occurring during pre-launch and launch operations.

The AIM Power Converter Unit (APCU) accepts raw bus power from the Power and Pyro Switching (PPS) subsystem's power bus and provides conditioned power for all assemblies on the VME bus (+5v) and provides additional voltage levels for the MFC (+3.3 v), the HCD (+12v), and the VME bus (+3.0v). The APCU is a new design based on commercially available DC to DC converters, that have undergone a special high temperature burn-in tests to demonstrate reliability.

The "down link" board consists of the Reed-Solomon Down link (RSDL) and Timing Unit (TU) functions. The RSDL is the down link data exit point from the AIM to the Telecommunications subsystem and Support Equipment (SE). It appends a synchronization pattern to the front of each transfer frame and a Reed-Solomon encoding pattern to the end of each transfer frame. The TU provides basic timing functions for the AIM including maintaining spacecraft time. The design of the RSDL is based on that of the Cassini spacecraft with modifications to accommodate the VME bus interface and the need to routinely update spacecraft time.

The "uplink" board is the Hardware Command Decoder (HCD) board shown in Figure 2. It contains the Critical Relay Controller (CRC), Bus Controller (BC) and Hardware Command Decoding functions. The HCD is the uplink data entry point to the AIM from the Telecommunications subsystem (TEL). The CRC portion handles error-detection-and-correction (EDAC) and critical command logic. The BC provides a modified 1553B bus (non-transformer coupled for reduced power). The design of the HCD is based on that of the Cassini spacecraft with modifications to accommodate the VME bus interface and modified 1553B bus interface.

The BC in the HCD is used to operate two Remote Engineering Units (REUs) to collect temperature data, analog signals, digital data from various locations on the spacecraft and to control many of the peripherals on the spacecraft. The Bus Controller also provides an interface to the Support Equipment (SE). The REUs digitize temperature and analog data and provide this information on request via the modified 1553 bus. “Out-board peripherals are controlled via the REUs; all digital input and output signals pass through the appropriate interface unit [Lander Interface Unit (LIF) or Cruise Stage Interface Unit (CSIF)]. The REU design is based on that of the Cassini spacecraft with modifications to accommodate the VME bus interface. The REUs are identical. They are labeled the Lander REU (LREU) and Cruise Stage REU (CREU).

The LREU's primary interface is to the Lander Interface (LIF). The LIF collects data from and sends commands to the Radar Altimeter subsystem, Atmospheric Structure Instrument/Meteorology (ASI/MET) experiment, High-Gain Antenna Drive Electronics (HGADE), and ACCEL assemblies. The LIF is designed to mate the LREU and the out-board assemblies.

The High-Gain Antenna Drive Electronics (HGADE) are used to control the pointing of the High-Gain Antenna (HGA). The AIM uses HGADE to command the HGA to track the Earth once the spacecraft has landed on Mars. The HGADE has two channels--one for each gimbal on the HGA. Each channel is powered separately directly from the power bus,

The ACCEL contains two sets of three, orthogonally mounted accelerometer packages. The two packages are identical and are called the ASI and AIM accelerometer packages. The ASI accelerometers are used to conduct atmospheric science during the EDL phase of the mission. The AIM accelerometer are used to measure the spacecraft’s deceleration profile during EDL. (The AIM subsystem uses this data to pick the time the parachute should be deployed.) The AIM accelerometers are also used to measure the local gravity vector following landing. Both the ASI and AIM accelerometers can be commanded to three levels of sensitivity: ± 16 mini-g’s, ± 800 mini-g’s, and ± 40 g’s to detect varying levels of atmospherically induced deceleration of the spacecraft. Spacecraft protection is designed such that the ASI accelerometers can be used as back-ups in case of failures in the AIM accelerometers.

The Lander PCU (LPCU) accepts input from the PPS Power Distribution Unit (PDU) and provides conditioned power for all non-VME bus assemblies in the Lander Module: LREU (+5v,*12v), LIF (+5v, ±12v), Radar Altimeter Subsystem (+30 v), and the ACCEL (+5v, ±15v). The LPCU is designed so the ACCEL and Radar Altimeter can be turned on or off while the LIF remains on; note the three power taps on the LPCU in figure 1. The LPCU is a new design based on commercially available Class B PCU components.

The second AIM REU is the CREU, and its primary interface is to the Cruise Stage Interface (CSIF). The CSIF collects data from and sends commands to the Star Scanner Electronics, Digital Sun Sensor Electronics (DSE), and Propulsion Drive Electronics (PDE). The CSIF is designed to mate the CREU and these out-board assemblies.

A Ball IUS CS-203 Star Scanner or Star Scanner Assembly (SSA) is the primary source of spacecraft inertial attitude information. The SSA is composed of the Star Scanner Electronics (SSE) and Star Scanner Baffle (SSB). The SSA is the design used on the Magellan spacecraft and the Inertial Upper Stage (IUS) booster rockets. JPL is modifying the Ball scanners that are in flight project stores (9 units) to accommodate the Pathfinder spacecraft spin rate of approximately 2 rpm. Other performance requirements on the SSA are as follows:

- “Accuracy (3 sigma) of 0.10
- Number of stars: 2
- Star sensitivity to +2.5 magnitude

- Star magnitude accuracy of +/-0.5 (dimmest star)
- Probability of detection > 95%
- Probability of false detection < 1 %

The "V" slit type scanner will detect star pulses and provide magnitude. The data will then be compared to an on-board star catalog. From this, three-axis spacecraft attitude determination can be performed. The Star Scanner electronics is dual (redundant) string. Each SSA string can be powered separately using the PPS PDU. The modifications to the SSA engineering model have been made. Performance tests have demonstrated satisfactorily results.

Adcole provides the Mars Pathfinder Digital Sun Sensor Assembly (DSA). This design is virtually identical to sun sensor used on the Mars Observer spacecraft. The design of the sun sensor will be modified to accommodate the power bus voltage variation (27v - 36v) of the Mars Pathfinder spacecraft. The Sun Sensor is comprised of five detector heads each with a field of view of 128 degrees and a single electronics interface package. The five heads will allow for full-sky coverage except for a 20 degree full cone obstruction due to the aeroshell. Accuracy of the sun sensor will be within 0.5 degrees (3s). The DSA gets power from the PPS PDU.

The Propulsion Drive Electronics, or PDE, control the monopropellant, blowdown propulsion subsystem. The PDE actuates 4.45 N thrusters for spacecraft attitude keeping, turns, and trajectory correction maneuvers. The PDE is also used by flight software to power catbed heaters and actuate latch valves to open fuel lines or isolate thruster branches.

The PDE is composed of three separate electronics boards. PDE1 is the controller; it carries the logic and circuitry to generate telemetry and execute commands from the flight software. PDE2 carries the drive electronics; PDE2 switches current to drive the heaters and valves within the propulsion subsystem. PDE2 also contains a PCU to regulate the voltage applied to the isolation valves, thrusters, and catbed heaters.

The Cruise Stage PCU (CPCU) accepts input from the power bus and provides conditioned power for all assemblies in the Cruise Stage Module: CREU (+5v, ±12v), CSIF (+5v, 312v), and the Propulsion Drive Electronics (PDE1) (+5v, ±12v). The CPCU is a new design based on commercially available Class B PCU components.

AIM Flight software is developed using the "C-language" and tested to a detailed verification test matrix. This allows the development of flight software at different sites because it is a well known language and is easily portable. The flight software will be thoroughly tested during subsystem and system integration and test prior to installing hazardous components on-board the Flight System (i.e. monopropellant hydrazine, pyrotechnic squibs, etc.). To inhibit inadvertent thruster firings during launch pad operations, the AIM flight software must issue a command to open the isolation latch valves and another command to open thruster valves to actually fire a thruster. In addition, the PDE drive power is inhibited by the separation breakwire until the flight system/third stage separation takes place in flight. A ground software check will be added to alert operators of this potentially hazardous condition.

Though the majority of the AIM subsystem is single fault tolerate the flight software is able to protect against significant faults during the mission. The software has built into in the following algorithms:

- Command Loss
- Relay State Enforcement
- Battery Over-Temp Fault Protection
- Battery Discharge Current Protection
- Battery State of Charge Protection

- Double bit Errors in MFC DRAM
- M in./Max. spin rate constraint
- Maximum spin rate change
- Max. off-sun attitude constraint

IV - Concluding Remarks

Future landers may be launched to Mars as early as '98 in Mars Surveyor or Discovery Programs. Some of these landers will be close derivatives or smaller versions of Pathfinder. In addition, Hughes and Rockwell are accomplishing further study of small lander architecture this year in support of the Mars Surveyor Lander Program. One Discovery proposal under study is planning to land a Pathfinder near duplicate vehicle near the North Pole of Mars. Other landers will repackage Pathfinder's centralized system architecture using emerging micro electronics and lighter materials to reduce size and volume. This will have a ripple effect in reducing end to end mission cost, in particular to enable the use of smaller, less expensive launch vehicles.

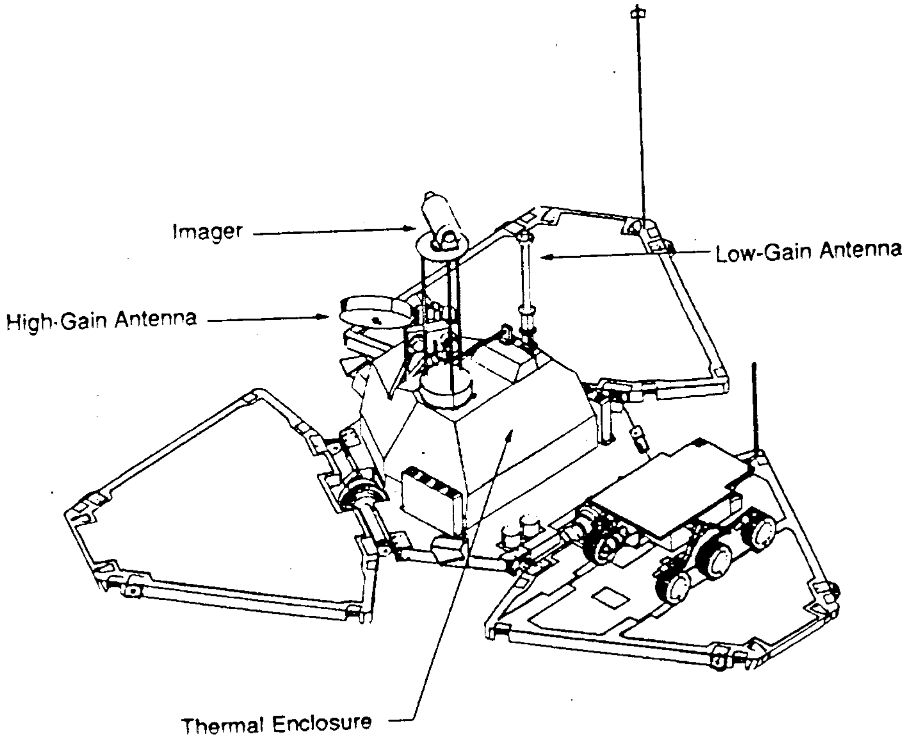
The Mars Pathfinder Attitude and information Management (AIM) subsystem is well along in the design cycle. Wc have completed its detailed design. The new electronic designs arc being fabricated, with about half of the subsystem undergoing assembly level testing. The software for the subsystem is also wc]] along, with the uplink and downlink functions tested out in the JPL's Flight System Testbed. In addition, we have been able to demonstrate in the Testbed the collection and compression of images from an engineering model camera and control of the prototype rover.

The major.. contributions of the AIM subsystem to future landers are the designs, developments, and lessons learned. In particular, it is a self-contained, solar powered flight system architecture built around a state of the art, powerful central computer that is used for cruise, EDL, and surface operations. It consolidates into onc subsystem what used to be implemented in numerous subsystems. In addition, the AIM subsystem is a small, light weight, low cost design developed on a fast track , schedule.

V - Acknowledgment

The research described in this paper was performed by the Jet Propulsion Laboratory, California institute of Technology, under contract with the National Aeronautics and Space Administration.

Figure <u>**Mars Pathfinder Lander Configuration**</u>



nteg ated Electronics Module

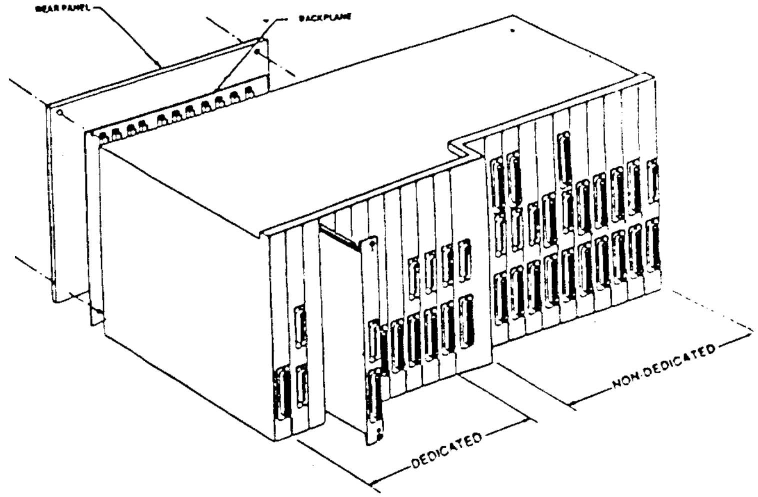
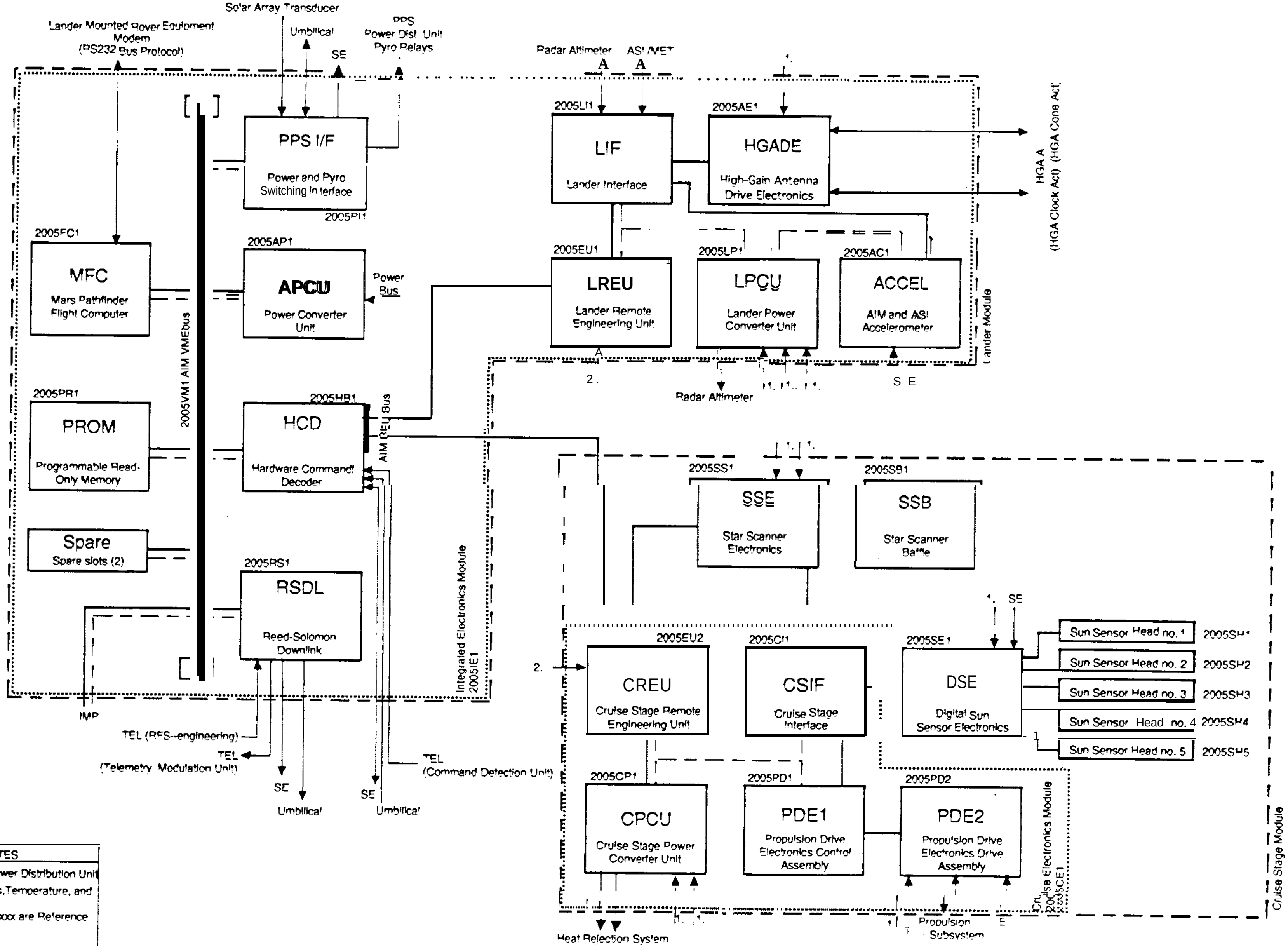


Figure 2 AIM Subsystem Block Diagram

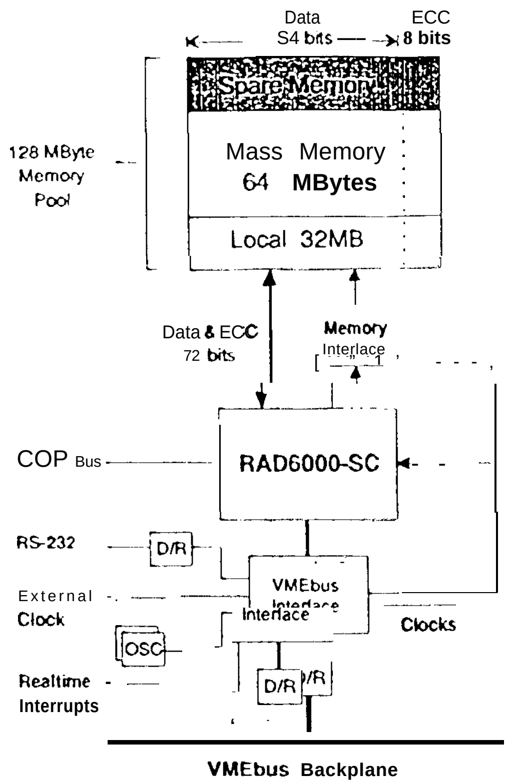


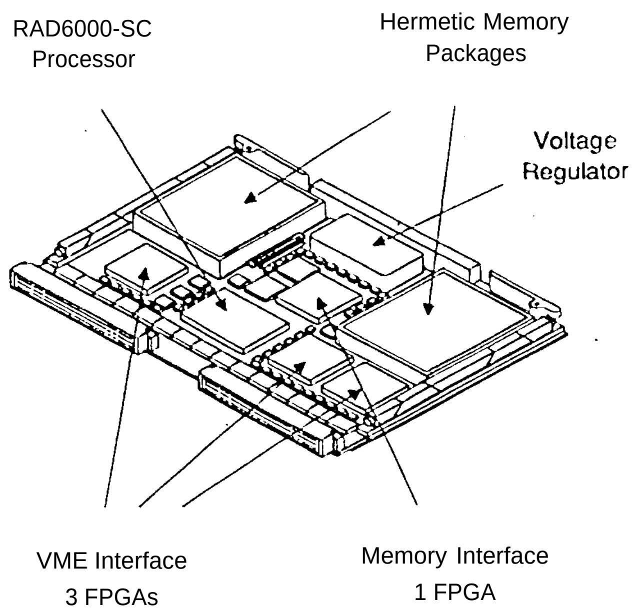
NOTES
1. From PPS Power Distribution Unit
2. Analog Signals, Temperature, and Discrete I/O
3. Numbers 2005xxx are Reference Designators

SE - Support Equipment
vwtwswmd.mm
— signal paths
— — power distribution

7/29/94

Table 1 Mars Pathfinder Flight Computer





CPU	IBM RAD6000-SC (Single Chip) includes: - Floating Point Unit - Fixed Point Unit - Common Onchip Processor (COP) Bu
CP U Speed	0.0 -22,1 VAX equivalent MIPs
Radiation Specs (all MFC parts, inc. memory)	2.8 SEUs/year (GCR only) No SEL @ 120 MeV/(mg/cm2) @ 125 deg C 50 krad TID
Memory	41 ligh DRAM Stack 128 Mbytes Mass Memory
Layout (see diagram)	1 VME 6U Board
Mass	0.9 kg
Power (including memory)	14.S W @ 22 MIPs 3.3 W @ 2,7 MIPs 2.5 W @ 0.0 MIPs
Reliability	0.9708 for 24 month mission
Bus	VME, IEEE 1014-1987, 10 Mbytes/Sec as Driven by MFC
Flight Realtime Operating System (FRTOS)	Open OS Operating System
Software Development	IBM RISC System/6000 "C" Software Development Tools and Capabilities